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ARMORED FORCE MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project Nos. 3-1 and 3-5
File No. 724.41

February 15, 1943

CONTROL OF GUN FUMES IN M-4 SERIES MEDIUM TANKS

1. PROJECT: Determination of the Characteristics and Effects Upon the Crew of Gun Fumes from Firing of the Weapons in Tanks of the M-4 Medium Series and Development of Effective Control.

a. Authority - Letter Commanding General, Headquarters Armored Force, Fort Knox, Kentucky, 400.112/6 GNOHD, dated September 24, 1942.

b. Purpose - To determine the magnitude of the hazard resulting from the gun fumes in the M-4 series of medium tanks and the development of effective means for the control of the hazard.

2. DISCUSSION:

a. Methods -

(1) Fire pattern. The quantity of gas released inside the tanks in a given period of time increases with the rate of gun fire. It is necessary, therefore, to employ a standard fire pattern in the evaluation of the hazard which approximates the maximum rate which may be encountered in combat. In the tests reported herewith, the following fire patterns were employed:

75MM GUN

The gun was fired in bursts of five rounds each with a time interval of five minutes between bursts and approximately ten seconds between rounds. Six bursts or a total of thirty rounds were fired in a complete test which extended over a period of thirty minutes.

MACHINE GUN

One belt of 250 rounds was fired in approximately four minutes at a rate of two rounds every two seconds. Four belts were fired in a total period of twenty minutes to constitute a complete test. The average rate of fire was therefore 3000 rounds per hour.

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(2) Permissible gas concentrations. Of the gases produced by gun fire, carbon monoxide is the most important from the standpoint of toxicity. The maximum concentrations of this gas which may be breathed with safety varies with length of exposure. In these tests an average concentration of 0.05 percent was established as a maximum permissible value. For an exposure of one-half hour or less this atmospheric concentration will produce no perceptible effect, and for an exposure of one hour only a slight headache.

(3) Tank operation. The tank was completely buttoned-up and except in special tests the motor was operated at its normal idling speed. It was not possible to orient the tank with respect to wind direction, but in general the wind was from the rear.

(4) Ammunition. 75 mm: AP M-61 FNH and super HE M48. Machine gun: Calibre 30 ball.

3. CONCLUSIONS:

a. M-4 and M-4 A-1 tanks. The concentrations of carbon monoxide produced by the 75mm gun and by the turret and bow machine guns were below the maximum permissible concentrations of 0.05 percent. There was, however, definite eye irritation resulting from ammonia produced by the 75 mm gun.

b. M-4 A-2, M-4 A-3, and M-4 A-4 tanks.

(1) The concentration of carbon monoxide in the turret resulting from the firing of the 75mm gun exceeded the maximum concentration of 0.05 percent and is a very real hazard to tank personnel.

(2) The concentration of ammonia in the turret was such as to casue considerable eye irritation and watering. As a result, the commander and the gunner were frequently unable to see the target. This condition alone is serious enough to make necessary the installation of control measures.

(3) The concentration of oxides of nitrogen was within the permissible level.

(4) There was no accumulation of carbon monoxide from one burst to another with repeated firing of bursts at five minute intervals.

(5) The direction of air flow toward the rear of the tank prevents the passage of gun fumes from the turret into the bow. As a consequence, the driver and the assistant driver are not exposed to excessive concentrations of carbon monoxide from the 75mm gun.

(6) Concentrations of carbon monoxide generated by the turret and bow machine guns were below the permissible concentrations of 0.05 percent.

c. Control of gun fumes.

(1) Increasing the engine speed is an effective method of control of fumes from the 75 MM gun.

(2) A high velocity jet blowing down across the breech was also effective in controlling the fumes.

(3) An exhaust system directly over the breech of the gun which removed the contamination through the turret ventilator was found to be effective with or without the tank engine operating.

(4) The rate of exhaust ventilation required was 130 cfm with a total resistance of 0.55 inches, water gauge.

(5) An exhaust system which meets the above specifications has been installed in an M4A3 tank and was found not to limit the depression of the gun or otherwise interfere with normal operations in the turret. The essential requirements of the system are shown in Figure I accompanying this report. Power requirements and superiority of this method over others is discussed in Appendix III. The reasons for including the M4 and M4A1 models in this recommendation are also discussed in Appendix III. A pilot model is available at the Medical Research Laboratory.

4. RECOMMENDATIONS:

a. Install a turret exhaust system in all tanks of the M4 series to be shipped overseas.

b. Provide kits for the field installation of such an exhaust system in all M4 tanks now overseas.

c. The capacity of the exhaust system to be not less than 130 cubic feet per minute with the inlet located over the breech at recoil position. The essential requirements are shown in Figure 1 of the Appendix.

Submitted By:

Lt. Col. Hatch
Captain Nelson
Captain Horvath
Lieutenant Eichna
Lieutenant Walpole

APPROVED Willard Machle
WILLARD MACHLE
Lieut. Col., Medical Corps
Commanding

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#1 - Appendix I, Sampling and Analysis
#2 - Figure I, Essential Requirements of Exhaust System
#3 - Appendix II, Gun Fume Concentrations in M4 Series of Tanks, with Tables I thru IVa and Figures 2 and 3
#4 - Appendix III, Control of Gun Fumes in the M4 Series of Tanks, with Tables V thru VII, and Figures 4 thru 6

APPENDIX I

SAMPLING AND ANALYSIS

1. Carbon Monoxide.

a. Collection of air samples: Three methods were employed.

(1) The Mine Safety Appliances continuous indicator.
(2) Instantaneous samples in evacuated flasks for the determination of peak concentrations and clearance rates at the end of firing.
(3) Continuous samples in evacuated flasks, sampling being continued at a constant rate throughout a given test in order to determine the average concentration for a given condition. Samples were collected in this manner at one or more crew positions.

b. Blood samples for the determination of carbon monoxide content were obtained from the tank crew members in the standard manner before and at the end of all complete tests. They were not obtained in exploratory tests.

c. CO Analysis: Evacuated flask samples were analyzed by the iodine pentoxide method and blood samples by the Scholander-Roughten and Spectro Photometric methods. The MSA CO indicator was checked at regular intervals against known air-CO mixtures.

2. Concentrations of ammonia and oxides of nitrogen were determined in portions of the instantaneous flask samples, employing the Nessler and phenoldisulphonic acid procedures respectively.

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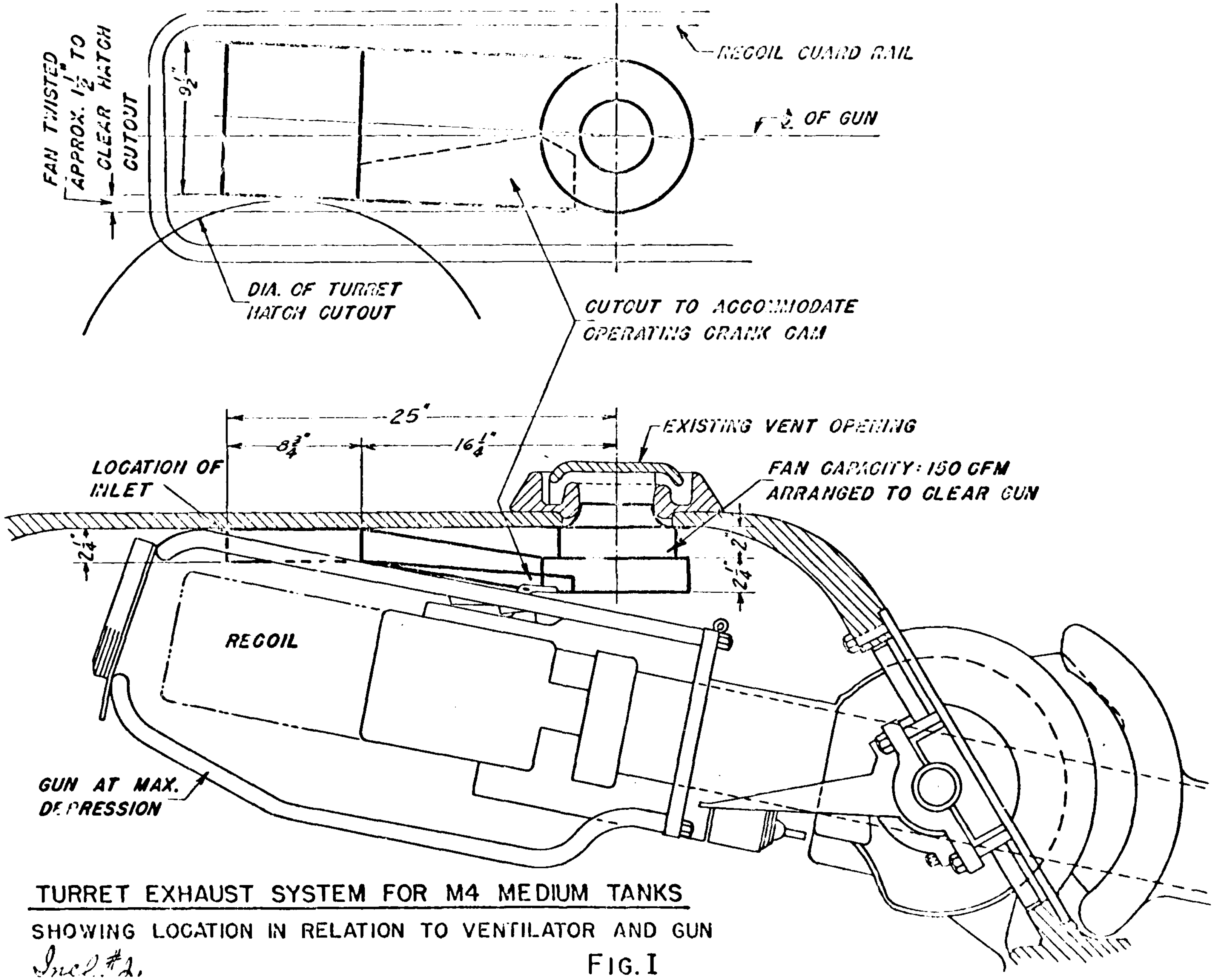

TURRET EXHAUST SYSTEM FOR M4 MEDIUM TANKS

SHOWING LOCATION IN RELATION TO VENTILATOR AND GUN

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FIG. I

APPENDIX II

GUN FUME CONCENTRATIONS IN M-4 SERIES OF TANKS

The results of gun fume tests in the standard M-4 series of tanks, with normal ventilation, are tabulated in Tables I to 4 and are shown graphically in Figures 2 and 3.

1. <u>75Mm Gun</u>.

The average concentrations of carbon monoxide from the 75Mm gun (Table I) were found to be in excess of the acceptable limit of 0.05 percent in the turret of the M-4 A-2, M-4 A-3 and M-4 A-4 tanks and somewhat below this value in the M-4 and M-4 A-1 tanks. The more favorable concentrations in the latter models result from the higher rates of ventilation which are provided. These tanks are operated by air-cooled engines and have two oil-cooling radiators in the bulkhead whereas the other models have only one. As a consequence of the greater area of openings in the bulkhead, more air is drawn through the fighting compartment into the engine compartment.

The concentration of CO at the driver's position in the bow of the M-4 A-3 tank was low, indicating that little of the contamination from the turret reaches this forward position in the tank.

Concentrations of carbon monoxide in the blood of the crew members (Table II) were in approximate agreement with the atmospheric concentrations, with the highest blood saturation values for the loader, and no significant increase in either of the two bow crew members.

There was no evidence of accumulation of carbon monoxide from one burst to another. This is shown for the M-4 A-3 in Figure III and similar results were obtained in the other tanks. It must be noted, however, that with higher rates of fire removal of the contamination would not be complete between bursts and, as a consequence, the average concentration of carbon monoxide would be higher. With a two minute interval between bursts, for example, the average CO concentration would be more than 2-1/2 times higher than the values here reported.

Ammonia was found to be troublesome in the turret and in certain tests was sufficiently strong to cause irritation of the nose and eyes with considerable watering of the latter. Concentrations of ammonia immediately after the fifth round of a single burst and the subjective symptoms of the turret crew members are given in Table III. It will be noted that the commander and even the gunner suffered some temporary loss of effective vision as a result of the irritation. This is obviously undesirable since it occurs at a critical time when these two crew members are in particular

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need for maximum vision. Quite apart from the more subtle action of carbon monoxide, this immediate effect is sufficiently serious to require effective control of gun fumes.

Oxides of nitrogen were found to be present in the gun fumes but never in concentrations above 15ppm, which is well within the safe concentration for the period of exposure involved. Concentrations of methemoglobin in the blood of crew members were also found to be insignificant. Thus, the oxides of nitrogen may be considered unimportant, from the present findings.

2. Machine Guns.

Carbon monoxide concentrations resulting from operations of the turret and bow machine guns (Table IV) did not exceed 0.05 percent in the M-4 A-3 tanks. Ammonia concentrations were also low (Table IVa) and no eye irritation was reported.

Since the ventilation in this tank is no better, basically, than in the M-4 A-2 and M-4 A-4 tanks the findings reported in Table IV may be considered representative of all three. In the case of the M-4 and M-4 A-1 models, lower concentration undoubtedly would be found, as was the case with the 75Mm gun. It is to be noted that little of the contamination from the turret machine gun reached the bow crew members, and conversely, the turret crew members were not affected by the operation of the bow machine gun. Blood concentrations of carbon monoxide for various crew members are given in Table IVa. It is evident from these findings that the bow and turret machine guns do not produce a hazard or unpleasant eye irritation when fired at a rate of 3000 rounds per hour.

3. CONCLUSIONS.

From the foregoing data, it is concluded that more effective removal of gun fumes from the 75Mm gun is required in the M-4 series of tanks. The M-4 and M-4 A-1 are included in this recommendation, in spite of their favorable showing with respect to carbon monoxide, because of the eye irritation noted in the turret crew members, and the fact that when used as pill-boxes with the tank motor not running, these tanks are no better than the others of the series.

If the proposed changes in tank ventilation cannot be made in all tanks immediately it would be desirable to equip the M-4 A-2, M-4 A-3 and M-4 A-4 models first.

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TABLE I

CARBON MONOXIDE CONCENTRATIONS FROM 75Mm GUN
And
CLEARANCE RATES IN SERIES M-4 TANKS

Standard Conditions of Ventilation

Tank Model	No. of Bursts	Average Concentration-Percent					Average Peak Conc. Percent Loader	Clearance Rate *
		Loader by MSA	Cont. Flask Samples					
			Loader	Commander	Gunner	Bow		
M4	6	0.039	0.037	0.029	0.022		0.247	5 Sec.
M4 A1	2		0.031				0.243	17 Sec.
M4 A2	2	0.054	0.125				0.350	33 Sec.
M4 A3	6	0.070	0.099		0.122	0.016	0.330	32 Sec.
M4 A4	6			0.123			0.330	50 Sec.

* Time to clear 50 percent after five rounds fired

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TABLE II

BLOOD CONCENTRATIONS OF CARBON MONOXIDE IN CREW MEMBERS
AFTER FIRING 6 BURSTS WITH 75Mm GUN
(30 Min. exp. to cyclical CO conc. in Air)

Tank	Crew Member	CO Hemoglobin Percent Total Pigment			Aver. CO. conc. in Air (Cont. Flask Sample)
		Before Exp.	After Exp.	Increase	
M4 75Mm Gun	Loader	0	13.3	13.3	0.037
	Commander	0	4.5	4.5	0.029
	Gunner	0.5	4.5	4.0	0.022
M4 A3 75Mm Gun	Loader	0.1	20.0	19.9	
	Commander	0.0	14.3	14.3	0.087
	Gunner	4.9	15.0	10.1	0.108
	Driver	5.0	5.9	0.9	
	Asst. Driver	1.4	1.7	0.3	0.016
M4 A4 75Mm Gun	Loader	0	22.5	22.5	
	Commander	1.5	14.7	13.2	0.123
	Gunner	3.3	8.8	5.5	
	Driver	2.8	4.3	1.5	
	Asst. Driver		2.6		

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TABLE III

AMMONIA CONCENTRATIONS FROM 75Mm GUN
And
REPORTED EYE EFFECT

Tank	Range in Ammonia Conc. - ppm *	Effect Upon Eyes of Turret Crew		
		Loader	Commander	Gunner
M4	105 - 210	Irritation	Very little smarting	Very little smarting
M4 A2	240 to 270	Watering	Watering	Watering
M4 A3	180 to 410	Watering	Watering	Smarting
M4 A4	210 to 350	Mod. Smarting Watering	None	Mod. Smarting Watering

* At loader's position, approximately 10 seconds after 5th round of burst

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TABLE IV

CARBON MONOXIDE AND AMMONIA CONCENTRATIONS
FROM
MACHINE GUNS

Standard M-4 A-3 Tank

Gun	No. Belts Fired	Aver. HSA Loader	CARBON MONOXIDE CONCENTRATIONS - Percent				
			Spot Flask	Aver. Concentrations by Cont. Flask			
				Turret		Bow	
				Loader	Gunner	Driver	Asst. Driver
Turret Machine Gun	4		0.034*	0.046	0.018	0.017	
Bow Machine Gun	4		0.022**		0.006	0.015	0.050
			Ammonia Conc. - ppm Spot Samples at End of Each Belt				
Turret Machine Gun	4		30*				
Bow Machine Gun	4		2**				

* At Loader's Position in Turret, Average of 3 Samples.

** At Asst. Driver's Position in Bow, Average of 4 Samples.

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TABLE IVa

BLOOD CONCENTRATIONS OF CARBON MONOXIDE
IN CREW MEMBERS
AFTER FIRING 4 BELTS IN TURRET AND BOW MACHINE GUNS
(20 MIN. EXP.)

Gun	Crew Members	CO Hemoglobin Percent Total Pigment			CO Average Conc. in Air (Cont. Flask Sample)
		Before Exp.	After Exp.	Increase	
M4 A3 Turret Gun	Loader		4.8		0.046 %
	Gunner		7.2		0.018
	Driver		4.3		0.017
	Asst.Driver		2.6		
M4 A3 Bow Gun	Driver	4.3	3.9		0.015
	Asst.Driver	2.6	6.2	3.6	0.050

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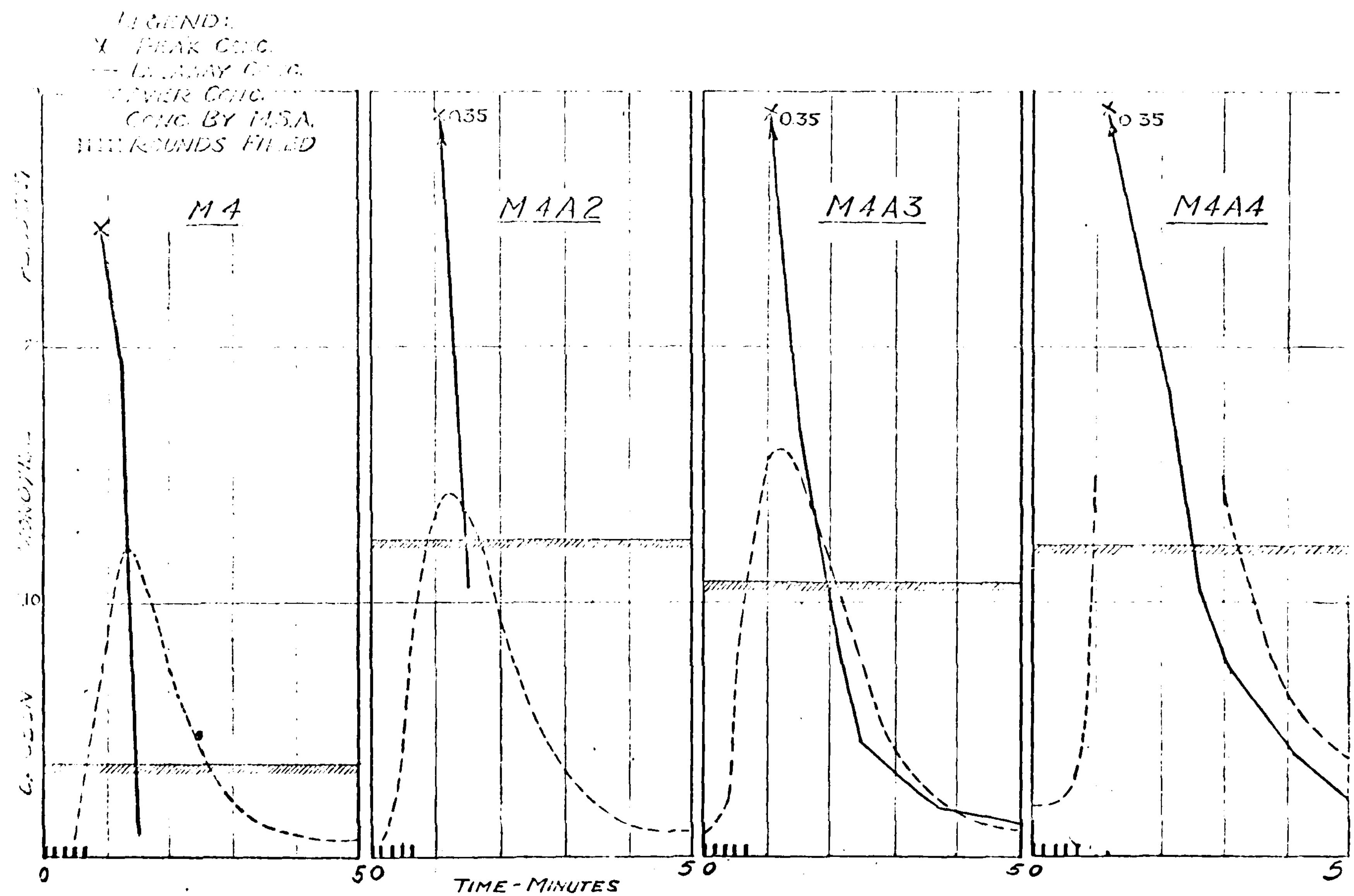

CARBON MONOXIDE CONCENTRATIONS FROM BURST OF FIRE OF FIVE ROUNDS 75 M.M.
STANDARD TANKS

FIG 2

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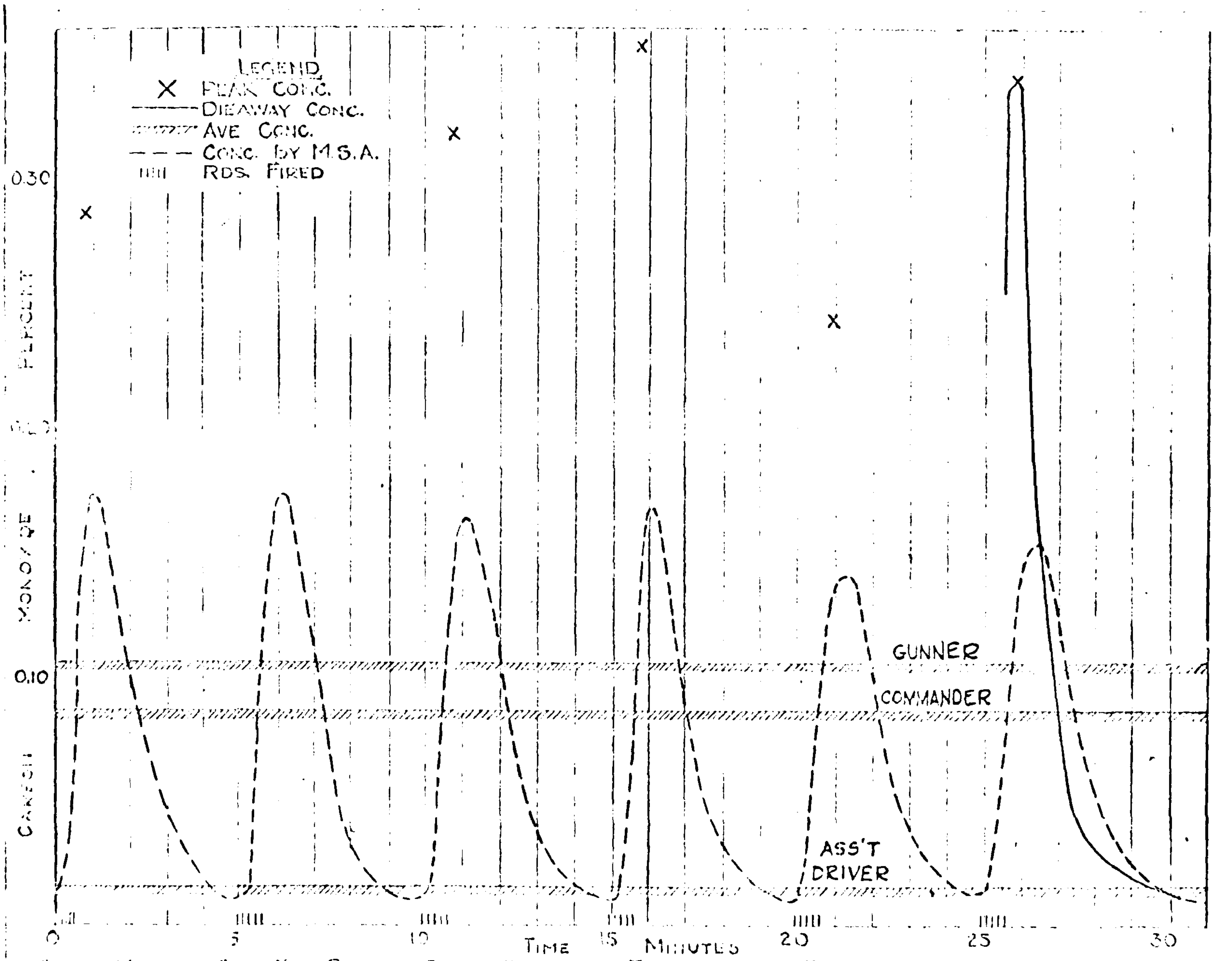

CARBON MONOXIDE CONC. FROM REPEATED FIRE OF BURSTS OF FIVE ROUNDS 75 MM STANDARD M4A3

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FIG. 3

APPENDIX III

CONTROL OF GUN FUMES IN THE M-4 SERIES OF TANKS

Ventilation of the fighting compartment of the M-4 Series of tanks is incidental to the engine ventilation. The engine-cooling fan draws some of its air from the fighting compartment through one or two radiators and certain other openings in the bulkhead. The primary purpose of this air is to cool the transmission oil, and in the case of an air-cooled tank motor, the engine oil. Air gains entrance into the fighting compartment through four special ventilators in the hull and turret and through other cracks and joints in the structure, such as around the 75Mm gun.

The rate of ventilation through the fighting compartment is a function of the engine speed and is at a minimum when the tank is buttoned-up and the engine operating at its idling speed. It falls, of course, substantially to zero when the tank engine is not running. Since the guns are most commonly fired when the engine is idling it is clear that effective means for control of gun fumes must be provided when the rate of tank ventilation is at a minumum.

The distribution of air flow through the fighting compartment is not uniform. It has been found, for example, that the rate of effective ventilation in the turret is only one-quarter of the total rate of ventilation through the tanks. Thus, the concentration of gun fumes which builds up in the turret is four times higher than it would be if the ventilation were uniform throughout the tanks. In this connection, it may be noted that the special ventilators, owing to their limited capacity, have little influence upon the distribution of air flow. The flow through a single ventilator amounts to only 9 percent of the total.

Three methods of control of gun fumes were investigated:

1. Increasing Rate of Ventilation by Increasing Engine Speed. This method has the advantage of requiring no modification in the tanks or its parts and is immediately applicable to tanks in the field. Its disadvantages are that it requires coordination of function between the driver and gunner and is undesirable from the standpoint of engine maintenance. The vibration produced may also interfere with effective gunnery.

2. Improving Distribution of Air Flow Within the Tanks. Since the rate of effective ventilation in the turret is only one-quarter of the overall rate of tank ventilation, more complete internal air mixing would reduce the carbon monoxide concentration. The power required to increase the effective ventilation rate in the turret by this means should be less than that required to provide an actual increase in the flow of outside air through the turret.

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3. <u>Removal of Gun Fumes by Exhaust Ventilation Through the Turret Roof Ventilator</u>. This method contemplates the direct removal of fumes as they escape from the gun and before being dispersed into the surrounding atmosphere. It should be independent of the main tank ventilation and work effectively when the tank engine is not running. Limitations in this method are that the installation must not interfere with normal elevation and depression of the gun and the power requirements must not exceed the supply available.

The three methods of control of fumes from the 75MM gun have been investigated, with the results reported below:

1. <u>Increasing Engine Speed</u>.

In these tests the engine speed was increased before firing started and was maintained at the higher RPM for two minutes during each burst. The resulting carbon monoxide concentrations in the turrets of the M-4 A-2 and M-4 A-3 tanks at increased engine speeds are compared with the results obtained at normal idling speeds in Table V, and are represented graphically in Figure 4. The increased ventilation obtained by this means reduces the average CO concentration below the acceptable concentration of 0.05 percent. It is of interest to note, that the peak concentrations immediately after the fifth round were not reduced. The rate of clearance however, was increased three-fold or more, and as a consequence, the average concentration was reduced. It is evident that this is an effective method of controlling gun fumes.

<u>TABLE V</u>

CARBON MONOXIDE AND AMMONIA CONCENTRATIONS FROM 75MM GUN
AND
CLEARANCE RATES AT VARIOUS ENGINE SPEEDS

Tank Model	No of Bursts	Engine Speed RPM	CARBON MONOXIDE - PERCENT: Aver. Conc. Thru Burst At Loader's Position By MSA	Cont. Flask	Aver. Peak Conc. Loader	Clearance Rate	Peak Ammonia Conc. PPM
M4 A2	2	300-400	0.054	0.125	0.350	33 Sec	240-270
M4 A2	2	1150-1200	0.012	0.011	0.165	5 Sec	
M4 A3	6	500	0.070	0.099	0.330	32 Sec	160-410
M4 A3	2	1000	0.031	0.032	0.333	12 Sec	110-305
M4 A3	1	1500	0.017	0.020	0.649	5 Sec	340

Incl. # 4

2. Internal Air Mix[illegible].

Several methods of increasing the rate of effective ventilation in the turret were investigated with the results shown in Table VI and in Figure 5.

In the first test, a centrifugal fan with a capacity of 250 cfm was placed on the turret floor and arranged to draw in relatively clean air and blow it upwards across the breech in order to increase the rate of ventilation in the upper zone of the turret. With this change in ventilation the commander and gunner were completely free from contamination. No improvement was noted, however, at the loader's position. In spite of the greatly increased rate of ventilation, the gun fumes were not dispersed and diluted in the air stream before reaching the loader's breathing zone.

A centrifugal fan mounted directly over the breech and discharging toward the floor improved conditions but there was considerable rebound of the contaminated air from the turret floor which carried the gas back through the breathing zone of the loader.

Best results were obtained by means of a six inch propellor fan mounted over the gun and arranged to blow down against the breech mechanism rather than directly across the breech. The result was to create a downward air movement after deflection off of the gun. The "slug" of contamination was broken up as it emerged from the gun and there was little rebounding of the contaminated air. As shown in Figure 5, the carbon monoxide concentration at the loader's position was well below the acceptable maximum of 0.05 percent.

Another method of internal mixing which gave satisfactory results was to blow a small volume of air at high velocity downward across the breech at an angle toward the rear of the turret. The purpose of the high velocity jet was to break up the "slug" of contamination issuing from the gun, and mix it with the veltilating air stream and the low rate of air flow was employed so as to minimize rebound into the upper zone of the turret. Of the several methods of internal mixing, this has the greatest practical value owing to the fact that it requires only a small air supply tube mounted on the gun while the low-capacity fan can be located at a convenient remote spot. In contrast, a fan mounted directly over the gun would interfere with the normal depression of the gun.

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TABLE VI

CARBON MONOXIDE CONCENTRATIONS FROM 75Mm GUN
AND CLEARANCE RATES
INTERNAL AIR MIXING IN TURRET

Tank Model	Mixing Arrangement	CO Conc. - Percent			Clearance Rate
		Loader		Average Peak Conc Loader	
		By MSA	By Cont. Flask		
M4 A2	Centrifugal Fan on Floor Blowing Toward Breech at 250 CFM	0.067	0.105	0.365	30 Sec.
M4 A3	Centrifugal Fan Over Breech Blowing Down Velocity at Breech - 1000 FPM	0.056	0.070	0.400	30 Sec.
M4 A3	Centrifugal Fan Over Breech Blowing Down Velocity at Breech - 250 FPM	0.048	0.061	0.170	40 Sec.
M4 A3	6" Prop. Fan Over Breech Mechanism and Blowing Down	0.015	0.013*	0.103	
M4 A3	High Velocity Jet Blowing Down at Angle Toward Breech Air Vol-50cfm. Velocity at Breech - 5900 fpm	0.021	0.021*	0.076	

* Estimated from MSA readings

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3. Local Exhaust Ventilation.

The practical application of this method of control is determined by the space requirements of the apparatus (intake duct, fan and motor), the rate of exhaust ventilation required and the amount of power needed to force the air out through the restricted opening of the ventilator. The purpose of the test here reported was to determine the minimum rate of exhaust ventilation and the power requirements of an effective system. Results are shown in Table VII and Figure 6.

In the first test air was exhausted through the turret ventilator without any intake duct. There was considerable improvement in the turret atmosphere but owing to the distance from the gun breech to the ventilator the removal of gases was not complete. In subsequent tests an intake duct was carried from the ventilator along the roof to a point directly over the breech of the gun. Two tests were conducted with rates of air flow of 130 and 90 cfm respectively. The CO concentrations with the lower rate of air flow were below the limit of 0.05 percent but there was noticeable eye irritation. It is concluded, therefore, that the higher value of 130 cfm represents the minimum effective rate of exhaust ventilation.

Of great practical importance is the fact that the exhaust system gave satisfactory control of gun fumes without any general ventilation of the fighting compartment, that is, with the tank engine not running. No eye irritation was reported with the exhaust system in operation.

The overall resistance of the exhaust system with 130 cfm was 0.55 inches, water gauge. Thus, the theoretical power required to operate the system is less than 10 watts. Owing to the restricted space over the gun, however, and the limited area of opening into the ventilator, the conditions are not favorable for the installation of a highly efficient fan. In fact, a fan of special design is required if high fan speed is to be avoided. An efficiency of 30 to 40 percent would increase the power requirement to 30-40 watts.

An exhaust system with intake duct, special fan and motor is now being built which will fit into the allowable space and not interfere with the depression of the gun. The system is shown diagramatically in Figure I.

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TABLE VII

CARBON MONOXIDE CONCENTRATIONS FROM 75Mm GUN
AND CLEARANCE RATES
EXHAUST VENTILATION IN TURRET

Tank Model	Exhaust Arrangement	CO CONC. - PERCENT			Clear-ance Rate	Peak Ammonia Conc. PPM
		Loader		Average Peak Conc. Loader		
		By MSA	By Cont. Flask			
M4 A3	Exhaust at 130 Cfm Thru Turret Vent. No Inlet Duct	0.037	0.051	0.206		125
M4 A3	Exhaust at 90 Cfm Inlet Duct Opening Over Breech	0.036	0.043*			
M4 A3	Exhaust at 130 CFM Inlet Duct Opening Over Breech	0.020	0.016	0.119	16 Sec.	65
M4 A3	Exhaust at 130 CFM Inlet Duct Opening Over Breech. Engine Not Running	0.031	0.014	0.109	25 Sec.	80-140

* Estimated from MSA

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OUTLINE OF PROPOSED INSTRUCTION ON
DANGER FROM GUN FUMES AND MEANS OF CONTROL IN M4 TANKS

1. Firing of the 75 mm gun at rates like those used in combat contaminates the air of the turret with carbon monoxide and ammonia even when the tank engine is operating at normal idling speed.

2. This results in serious eye irritation in a few moments and may cause severe headache and even unconsciousness if firing is continued at high rates for longer than 30 minutes.

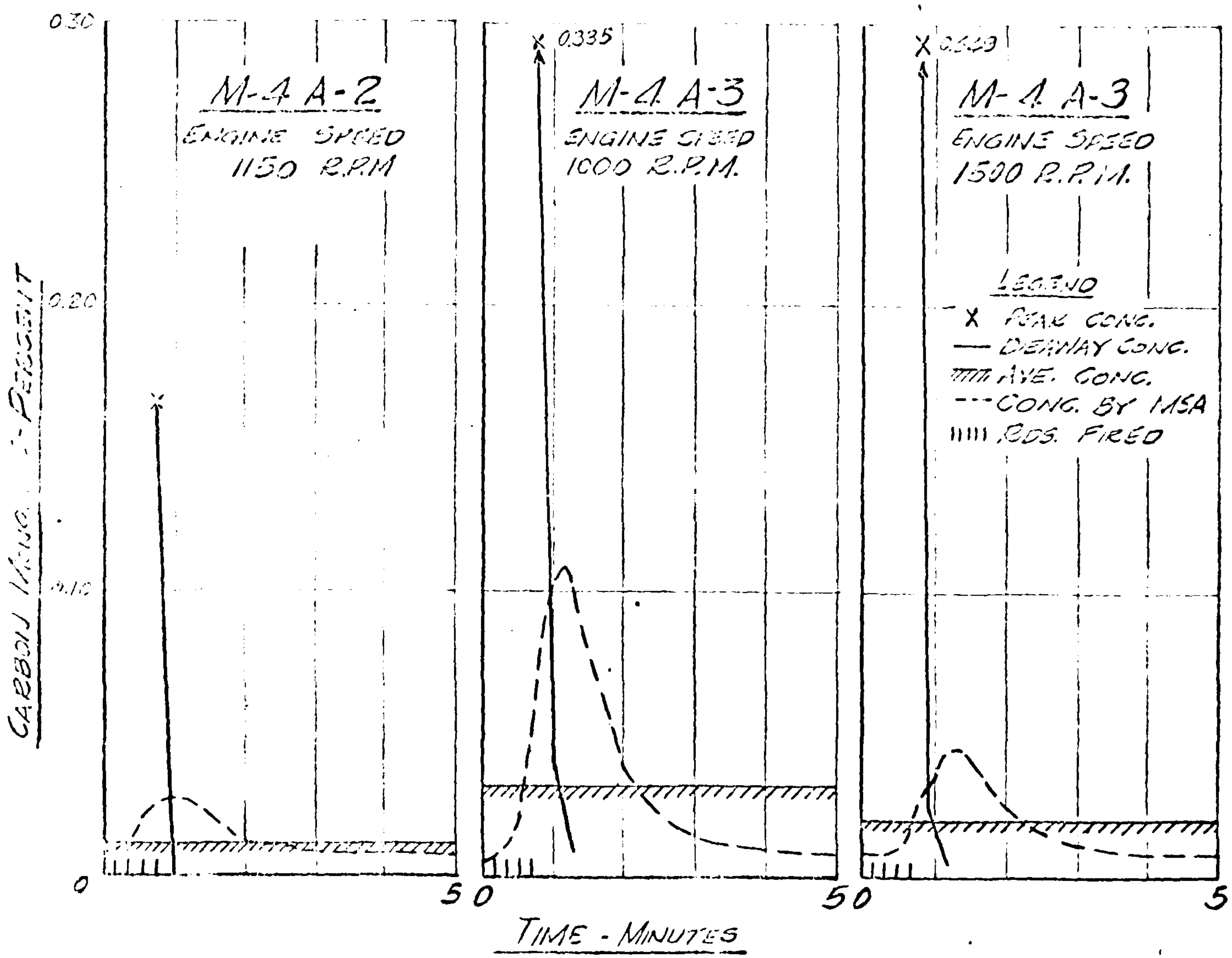
3. When the motor is dead and the tank buttoned-up, fumes become dangerous in a few minutes.

4. <u>PROTECTIVE MEASURES</u>.

<u>a</u>. When firing at high rates in a buttoned-up tank, the engine should be run at not less than double normal idling speed during the period of fire and thereafter until cleared of visible smoke.

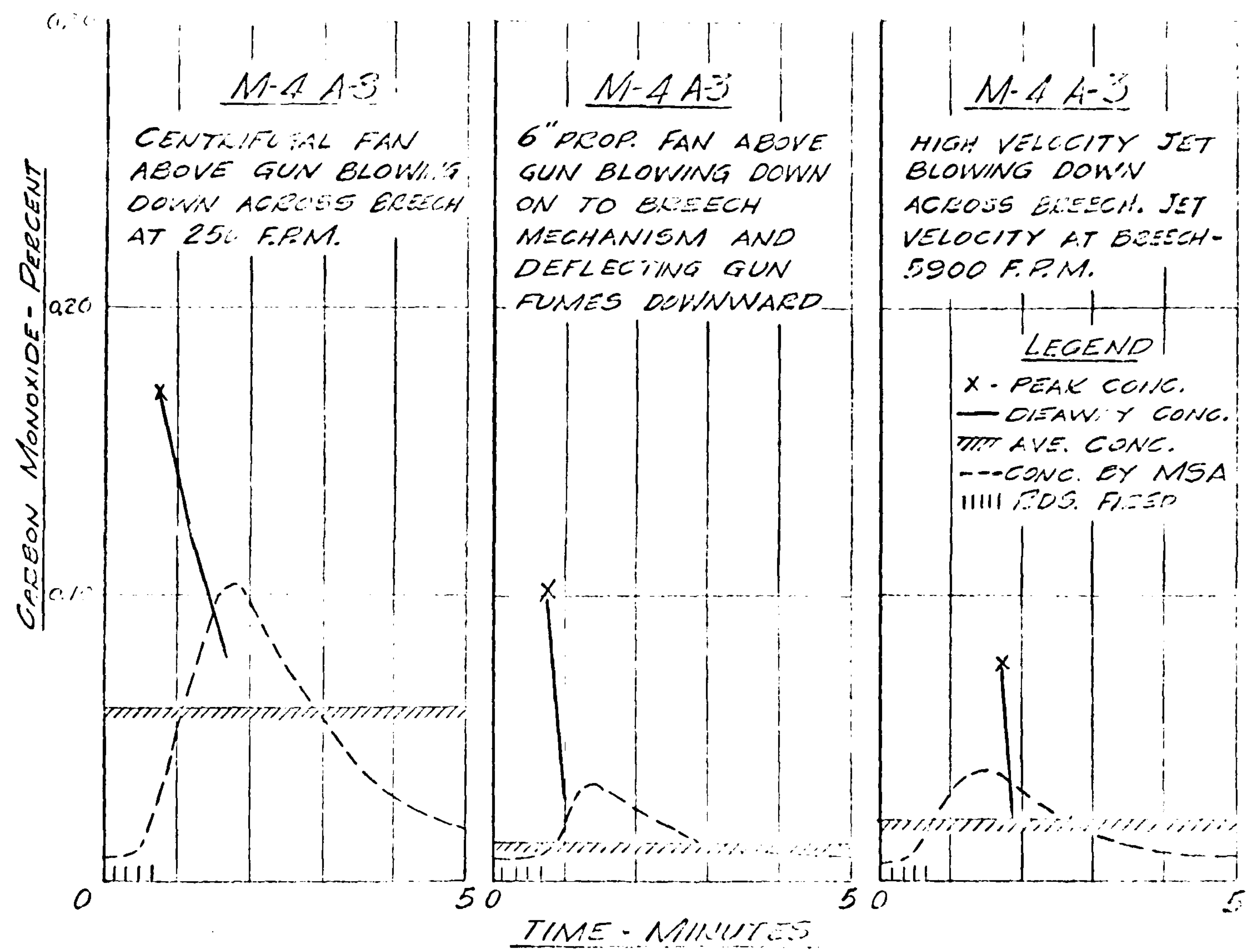
<u>b</u>. In combat, at any rate of fire, with the tank motor dead, the turret hatch lid should be partially open and the escape hatch dropped.

<u>c</u>. In training, when firing with the tank motor dead, the turret hatches should be open.



CARBON MONOXIDE CONCENTRATION FROM BURST OF FIRE OF FIVE ROUNDS 75MM AT HIGH ENGINE SPEEDS

FIG. 4



CARBON MONOXIDE CONCENTRATION FROM BURST OF FIRE OF FIVE ROUNDS 75MM WITH INTERNAL MIXING OF AIR IN TURRET

FIG. 5

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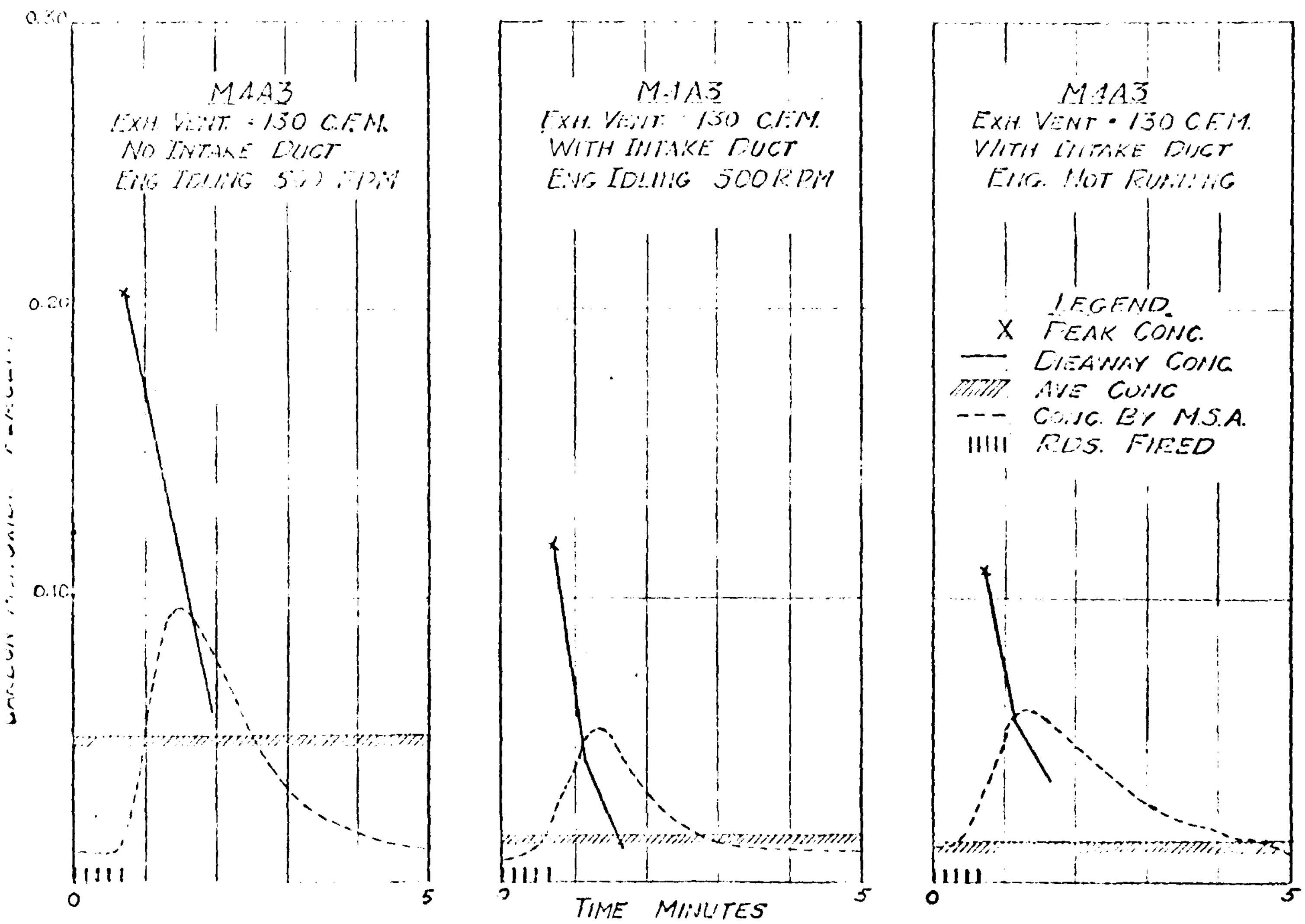

CARBON MONOXIDE CONCENTRATION FROM BURST OF FIRE OF FIVE ROUNDS
75 MM WITH EXHAUST VENTILATION IN TURRET

FIG. 8

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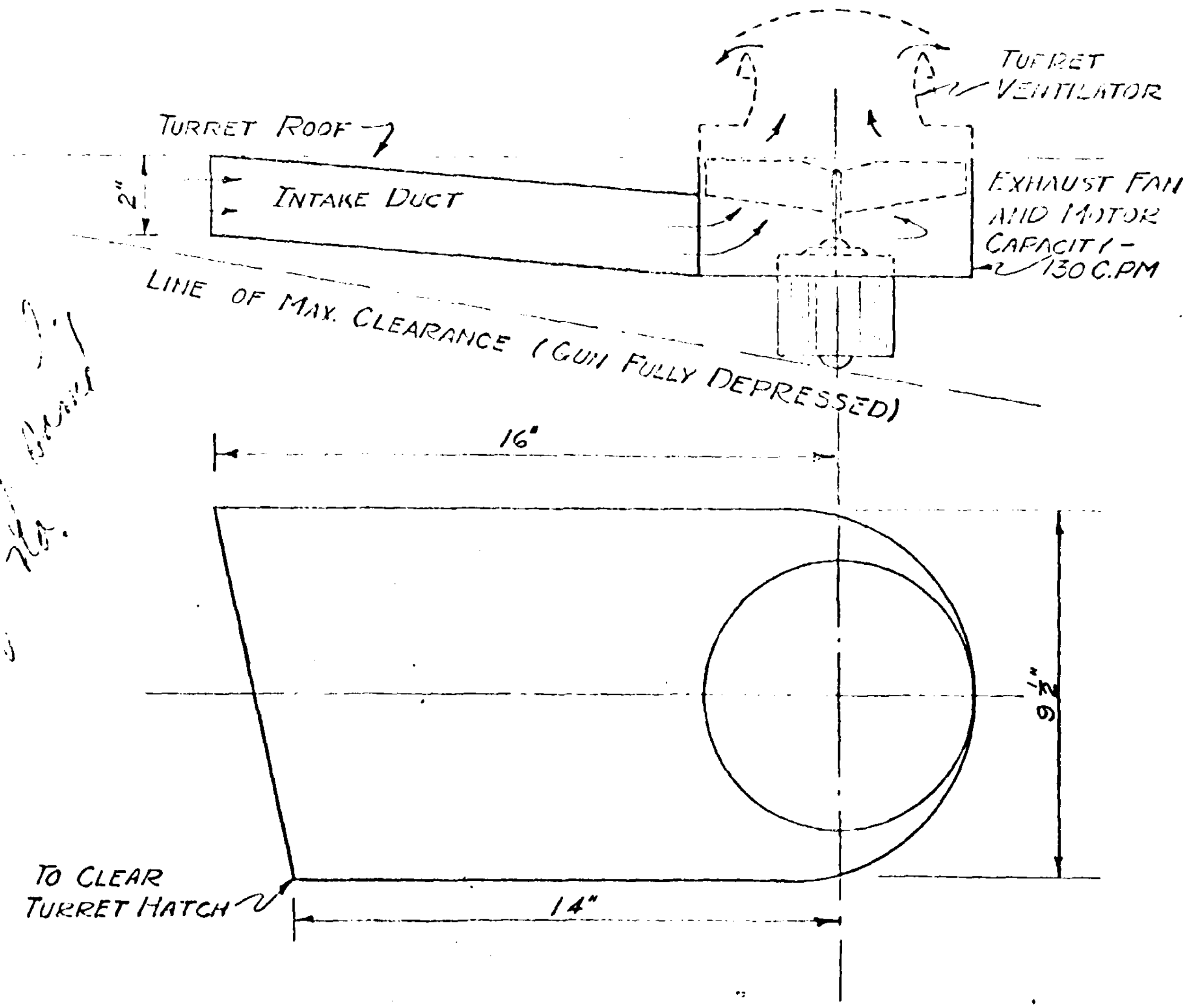

PROPOSED TURRET EXHAUST VENTILATOR FOR M4 MED. TANKS
(DIAGRAMATIC)

FIG 1.